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QUANTITATIVE PLANKTON STUDIES OF TURKEYFOOT LAKE, NEAR AKRON, OHIO

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INTRODUCTION

Turkeyfoot Lake is the southernmost of a chain of lakes and reservoirs known as the Portage Lakes, partly within but mostly south of the city of Akron. The three lakes farthest south, with connecting channels, all on one level higher than the other lakes, are shown on the accompanying map (Figure 1).

An entirely new reservoir, Nimisila, is in the process of filling up. It will have its outlet into the southern end of Turkeyfoot.

Turkeyfoot has an arm northwest called Rex Lake and a more broadly connected eastern lobe, Mud Lake, and the rest of it is partly divided into lobes. In the large, central southern lobe, collections were made in a central area having a depth of 13 to 14½ meters, maybe more at some places. The collecting station is marked "X." Besides plankton collections, bottom samples were made with Ekman dredge, but bottom organisms are not reported in this paper. One central station has been found adequate in some recent work (Ricker, 1938) for pelagic limnoplankton.

Near the entrance of Mud Lake into Turkeyfoot, marked "Y" on the map, collections were also made at two stations, both shallow, differing somewhat in nature of bottom, but these are not reported in this paper.

The aims were to show seasonal and vertical distribution of the chief plankton organisms. Temperature records and chemical tests of dissolved O_2, dissolved CO_2 and pH were made. No extensive limnological or ecological studies were possible in the limited time available.

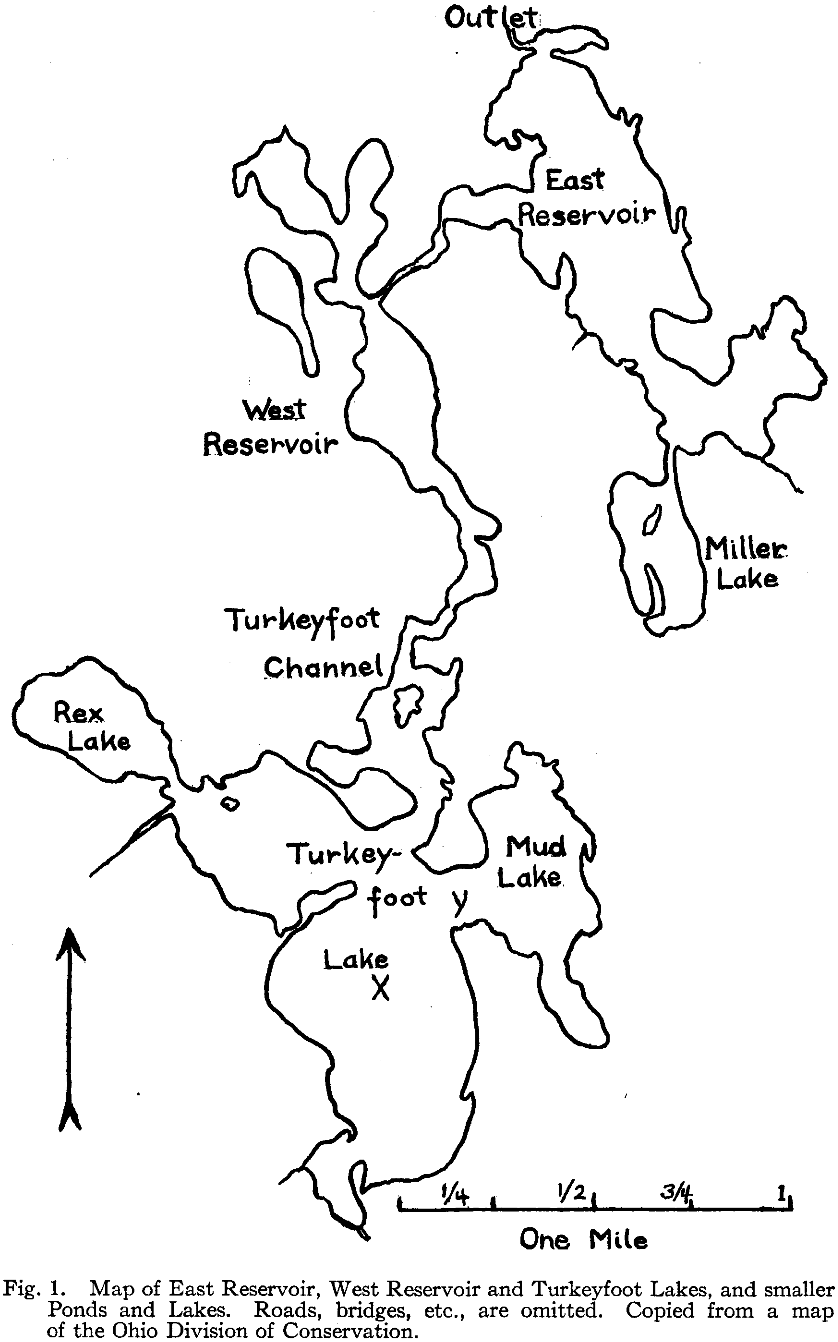

Fig. 1. Map of East Reservoir, West Reservoir and Turkeyfoot Lakes, and smaller Ponds and Lakes. Roads, bridges, etc., are omitted. Copied from a map of the Ohio Division of Conservation.

Very little has been published on these lakes, though much uncorrelated collecting has been done. One paper on net-plankton of East and West Reservoirs appeared (Kraatz, 1931). Recently a paper (Kraatz, 1940) which is part of this same study, appeared, serving as an introduction to the present paper.

ACKNOWLEDGMENTS

The Division of Conservation of Ohio donated a Foerst plankton trap, Kemmerer-Foerst water bottle and also an Ekman dredge; without this equipment the work would have been impossible. Particular thanks are due to Mr. E. L. Wickliff for securing this equipment and encouraging the work. At the beginning of this work Mr. Lee S. Roach demonstrated the collecting and laboratory methods as done in the state conservation work. Chemical tests were performed by Miss Eleanor Mueller and later by Mr. Samuel Caplin. On each collecting trip some student assistant or other student helped with the apparatus and collection. Mr. Walter K. Harris, Portage Lakes Conservation Officer, gave generously of his time, running the state motor boat on all trips, without which the collection would have been impossible.

Dr. L. H. Tiffany, and after his leaving Ohio, Dr. C. E. Taft, identified some algae and Dr. L. E. Noland, some Protozoa. The extent of their examination of various types of organisms is hardly realized in this paper, where only the main plankters appear. Mr. Bill J. Barkley copied the graphs in presentable form.

Microscopes, counting cells, and all chemical and other materials, and also the deep sea thermometer and Foerst centrifuge belong to the Biology Department, University of Akron.

PLANKTON COLLECTING AND LABORATORY METHODS

Collections were made monthly at a convenient time, usually on a Saturday, from about the 15th to the 20th of the month, starting in August, 1936. None were secured in December, 1936, or February, 1937; thin ice proved unsafe for walking to the collecting station, but too thick for the boat to get through. A small collection was made from the boat January, 1937. Collections continued from March through October, 1937. November, 1937, was unavoidably missed. On December 4 a small collection was made through rather thin ice, but only at the shallow Mud Lake station. In January, 1938, a collection unfortunately incomplete, was made through thick ice; in February, an incomplete one from boat; but complete collections from

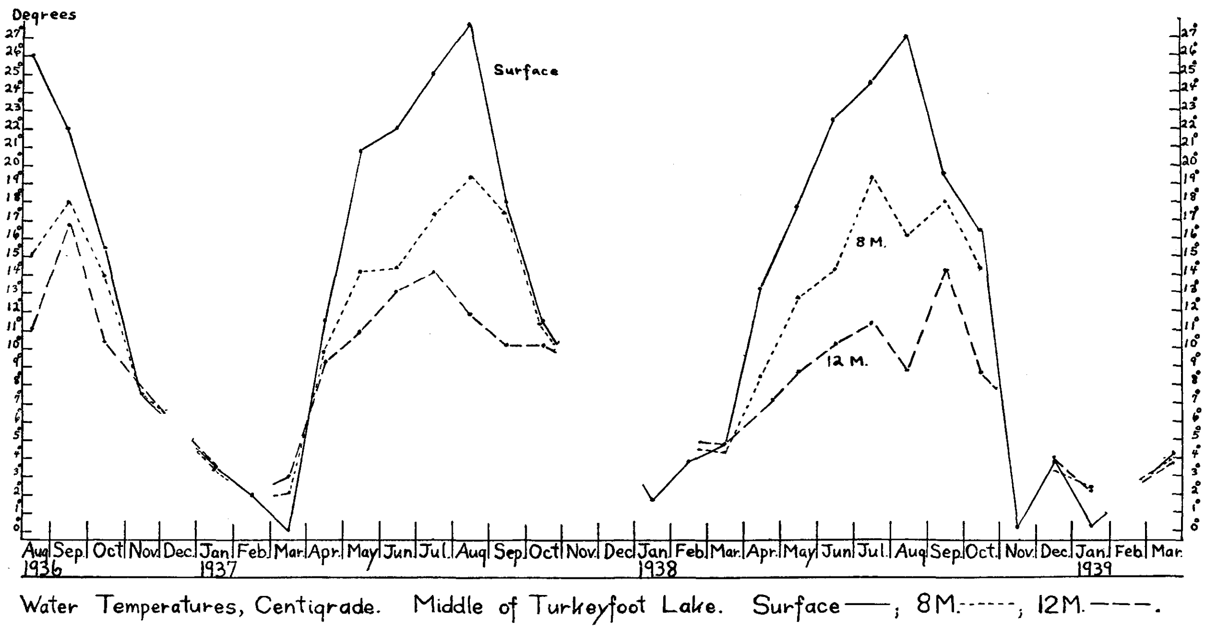

Fig. 2. Water Temperatures of Turkeyfoot Lake.

March onward. Circumstances again prevented a November collection, but an early December collection was made from a boat. A collection through ice was made January, 1939; none was possible due to weather conditions in February, but a final collection was made in March.

Methods of collecting have been adequately given in the paper referred to above (Kraatz, 1940) and likewise laboratory methods explained. The main aim of the paper was to compare the number of organisms per liter of lake water as secured by the trap concentrated by its net, with those secured by the water bottle, concentrated by the centrifuge. It was shown that for organisms falling within the general scope of netplankton, generally the trap was better, largely because, having a much larger initial sample and more concentrated laboratory vial sample and counting cell sample, much larger numbers of organisms were actually counted and less multiplying required to get organisms per liter, than in the case of the water bottle samples. It was shown that certain kinds of blue-green algae of low specific gravity were lost in centrifuging. But it was also seen that most kinds of diatoms were collected often in significantly larger numbers with the water bottle. The organisms per liter of net and centrifuge plankton in neighboring columns for all collections were studied and discrepancies compared as to their significance. Usually it was possible to determine for kinds or groups of organisms which technique was best. The selection is shown in the table and discussion later in this paper.

TEMPERATURE RECORD

A deep-sea reversing thermometer (H. B. Instrument Co.) was used from March, 1937, on. Previously an ordinary chemical thermometer was used by hurriedly placing it immediately after collection into the jar holding water from the brass water bottle as collected from just under surface, at 4 m., 8 m., and 12 m. These were the water samples later used for centrifuging. From August, 1936, to June, 1937, inclusive, records are available only for these four levels, but from July, 1937, to March, 1939, records were made at meter intervals. In certain winter months no records were secured from the middle of the lake.

The accompanying table shows the Turkeyfoot station "X" record, in centigrade for period in which meter interval readings were taken. The graph shows for the entire collecting period, the surface record, 8 m., and 12 m. records; the 4 m. curve very close to and slightly below the surface curve was not included because it would add to the confusion of lines. (See Table I and Fig. 2.)

It should be noted that the only temperature readings below ice from the middle of Turkeyfoot were January, 1938, (unfortunately only a surface reading) and January, 1939. Record marked * was close to shore at south end of lake; it was impossible to get out to the middle of the lake. One temperature record of surface water, March, 1937, was slightly below 0° C. The surface was not ice-covered; it was very windy and air temperatures below freezing. One temperature reading below ice in Mud Lake (station D) December, 1937, was 2.3° C.

TABLE I

WATER TEMPERATURE, DEGREES CENTIGRADE, MIDDLE TURKEYFOOT LAKE

	July 19, 1937	Aug. 20, 1937	Sept. 18, 1937	Oct. 16, 1937	Nov. 20, 1937	Dec. 4, 1937	Jan. 15, 1938	Feb. 19, 1938	Mar. 19, 1938	April 16, 1938	May 21, 1938	June 18, 1938	July 16, 1938	Aug. 20, 1938	Sept. 17, 1938	Oct. 15, 1938	Nov. 26, 1938	Dec. 3, 1938	Jan. 28, 1939	Feb. 25, 1939	Mar. 25, 1939
Surface	25.0	27.6	17.7	11.6			1.8	3.8	4.7	13.2	17.7	22.4	24.5	27.1	19.6	16.5	0.4	3.6	0.2		4.6
1 m	24.8	27.2	16.9	11.8					4.7	11.8	17.7	22.4	24.4	26.5	20.2	15.8	Off shore at Kelper's landing	3.6	1.8		4.4
2 m	24.5	27.1	17.4	11.6					4.4	11.6	17.7	22.4	24.4	26.4	20.2	15.6		3.6	2.0		4.4
3 m	24.4	26.8	17.5	11.6					4.4	10.9	17.6	22.2	24.3	26.2	21.0	15.6		3.6	2.2		4.4
4 m	24.0	25.2	17.4	11.5					4.8	10.4	16.6	22.0	24.3	26.0	20.6	15.5		3.4	2.2		4.3
5 m	22.1	22.7	17.0	11.5					4.8	10.2	15.6	20.2	24.4	24.0	20.6	15.4		3.4	2.2		4.4
6 m	20.6	21.5	17.4	11.5					4.4	9.7	15.6	20.1	23.0	22.5	20.6	15.0		3.4	2.2		4.0
7 m	19.2	19.2	17.4	11.4					4.4	9.1	14.5	17.0	21.1	18.8	20.2	14.6		3.3	2.3		4.0
8 m	17.3	19.4	17.4	11.4					4.4	8.5	12.9	14.4	19.4	16.2	18.0	14.4		3.3	2.3		4.0
9 m	17.0	14.8	14.7	11.2					4.3	8.0	12.1	9.6	16.3	15.5	16.0	13.8		3.3	2.4		4.0
10 m	14.6	12.3	12.4	11.2					4.2	8.0	9.8	9.9	10.4	12.9	15.4	11.6		3.4	2.4		4.0
11 m	14.4	11.6	10.3	10.8					4.6	7.4	8.7	8.2	9.4	9.8	14.8	10.4		3.4	2.6		3.9
12 m	14.1	11.8	10.2	10.2					4.6	7.1	8.6	10.2	11.4	8.8	14.4	8.6		3.8	2.2		3.9
13 m	12.0	11.8	*	9.1					4.6	6.4	7.9	8.3	12.1	8.0	9.8	8.8		3.8	2.5		3.8
14 m	11.8	10.4	*	*					*	*	7.5	7.8	11.4	8.8	*	8.7		3.8	*		3.8
15 m	11.0	10.2	*	*					*	*	*	*	*	*	*	*		*	*		*

Close similarity in seasonal temperature changes is shown in the two and one-half years of temperature curves. A series of spring and fall readings practically uniform from top to bottom indicates clear cut spring and fall overturns. No real thermocline can be noticed, however.

CHEMICAL TESTS

For chemical tests, made for each of the four levels surface, 4 m., 8 m., and 12 m., water was discharged from the brass water bottle into 250 cc. glass bottles which were tightly glass stoppered after being filled to overflowing. From each collection two such bottles were taken, the rest allowing for the liter centrifuge sample previously noted. A moist cloth over the bottles tended to keep down their temperature somewhat in transporting them back 9 miles to the laboratory, where tests were made. For the 32 month total period, 26 complete and two incomplete sets of samples for tests were available.

The outboard motor patrol boat used for most trips was so crowded that chemical tests on board were impossible. A much larger boat was available September and October, 1936, and from April to October, 1937, when it was removed from the lake. It could not be used in intervening months because the water level was too low in parts of the channels. But there was no thought of doing part of the chemical testing on board, until comparison of a year's oxygen records disclosed what seemed some rather unreasonably high quantities of dissolved oxygen. In September and October, 1937 trips, it was arranged to do the initial steps of the oxygen test on the big boat. These, after completion in laboratory, did show for reasons unknown somewhat lower oxygen content than the tests on water collected at same time, run entirely in the laboratory. The technique was precisely the same, and by the same person in this period of work; the method was the Rideal Stewart modification of the Winkler method. (Standard Methods of Water Analysis, 5th Ed., 1923.)

Because of a possible invalidity of the end results of some oxygen tests, it is not considered worth while to present a table of all results. Nevertheless, a summary is given, all figures being p.p.m. Surface water oxygen content varied from 6.13 (August, 1937) to 14.59 (January, 1938), but was usually between 10 and 14; of 28 surface monthly readings, the only ones below 10 were November, 1936, August, 1937, August, September and October, 1938, but also more oddly, March, 1939. For the most part oxygen content was high in spring. Several instances occurred of slightly higher oxygen content at 8 and 12 m. than at surface. Other surprises were some erratic ups and downs from month to month. But in many late summer and fall months, there was a marked decrease from top to bottom, especially in August and October, 1936, and June, August, September and October, 1938. The lowest content of all, at 12 m. was 2.20 in September, 1938. But usually the oxygen content at 4 m., 8 m., and 12 m., was not materially lower than surface content, in the fall overturn, November, during the winter, and during spring overturn, to beginning of summer.

The dissolved CO_2 was determined by the standard method of phenolphthalein indicator and n/44 sodium hydroxide. No CO_2 was recorded for surface waters except under ice, January, 1938, when there were 0.4 p.p.m. and in February, 1938, 0.2 p.p.m. At 4 m. there were 7 instances of some CO_2, at 8 m. 19 instances and at 12 m. 19 instances, out of 26 cases of total vertical test results. There were actually 6 monthly readings, January, March, and April, 1937, March and April, 1938, March, 1939, when the CO_2 readings were zero from top to bottom.

The pH was determined by the La Motte colorimetric method. Throughout the work, pH varied from 7.6 to 8.8 in surface water, higher alkalinity occurring in late summer and early fall. There were several cases of identical pH through the entire vertical range, 8.0 in April, 1937, March, 1938, 7.8 in December, 1938, and 7.6 in February, 1938. More often there was a slightly lower reading (less alkalinity) in deeper water, but the largest vertical range at any one time was 1.6 (and only 9 cases of ranges of 1.0 or above). The lowest alkalinity was 7.1 at 12 m., October, 1936, and the total range was 1.7.

KINDS OF PLANKTON ORGANISMS

Plankton were identified to genera. Species determination for all was impossible. In many cases a genus was represented by only one species.

Since routine examination was in the Sedgwick-Rafter counting cell, requiring low power (16 mm. objective) many nanno-plankton, if small and scattered, may have been omitted. Six types of real nanno-plankton were studied. Three of these were smaller species of genera also included in net plankton.

Twenty-seven net plankton genera and separately six nanno-plankton were tabulated completely. For each month or collection, the separate number of organisms per liter from surface water, 4 m., 8 m., and 12 m. were recorded. In this paper these longer tables are omitted.

Most of the data on organisms per liter of the twenty-seven genera were those of the trap-net collections; some were from the water bottle centrifuged samples. The selection was made on the basis of studies reported on in the paper comparing critically the two collecting methods (Kraatz, 1940) and referred to in the introductory remarks on methods, above.

The blue-green alga Aphanizomenon counts were from centrifuged samples because in times of maxima far greater numbers were secured than from trap-net samples. The other Cyanophyceae were from trap-net counts, because centrifuging operations failed to retain the vast majority of the water bottle specimens.

On the other hand, diatom counts used were from water bottle samples for in these significantly larger numbers were found, especially in times of maxima, though not at all times. One exception was Stephanodiscus where net counts were used. This may seem arbitrary, but this genus was found in far more net samples than water bottle samples; numbers of water bottle samples had none while the comparable net sample had appreciable numbers. Possibly this is explained by the combination of relatively small water bottle sample, with not

TABLE II

Plankton. Middle of Turkeyfoot Lake

Organisms per Liter; each Figure an Average of the Four Depth Levels

Organisms	Aug. 17, 1936	Sept. 19, 1936	Oct. 17, 1936	Nov. 14, 1936	Jan. 9, 1937	Mar. 27, 1937	April 24, 1937	May 22, 1937	June 19, 1937	July 19, 1937	Aug. 20, 1937	Sept. 18, 1937	Oct. 16, 1937
Coelosphaerium	3,650	11,169	6,531	6,700	75	38		414	2,899	3,750	4,325	544	91
Microcystis	2,325	3,344	5,881	387			1,488	242	509	1,600	1,886	95	47
Anabaena	9,612	9,331	1,419	44					4,368	42,102	6,700	874	50
Aphanizomenon	6,562	77,188	50,025	16,069	3,075	2,263	500	1,313	221,500	70,175	800	750	
Melosira	1,000	312	2,344	6,625		175	600	250	500	2,625	288	750	660
Stephanodiscus				278	513	863	400			1,900		50	100
Synedra	1,500	312	1,875	4,625	5,475	2,550	24,000	3.363	50		275	150	500
Asterionella			312	1,750	4,988	220,250	940,250	28,625	350				
Fragilaria	2,750	3,125	312	1,231	38	1,313	4,500	2,625	1,000	2.313	1,438		50
Pediastrum	75		4	5	2	51		10	4	17	2	2	7
Ceratium	3,958	1,229	171	12		2	7	92	4,760	2,301	823	73	14
Codonella			6	15	196	1,380	147				2	3	6
Polyarthra	40	51	53	56	10	20	139	237	22	255	99	116	447
Keratella	222	192	157	186	241	172	312	1,073	141	377	407	334	323
Asplancha					1	1	7	8	11		7	16	25
Synchaeta						1					41	115	24
Notholca	3	8	3	5	4	5	3	22	14	28	2	14	3
Nauplius	78	53	18	91	83	129	269	76	39	90	22	62	11
Cyclops	25	46	15	31	58	57	74	74	6	11	12	10	9
Diaptomus	15	8			3	1		16	8	4		1	2
Daphnia	10	8		3	2		10	59	5	5		1	
Bosmina		1		1	1		5	5			1	3	17

TABLE III

PLANKTON. MIDDLE OF TURKEYFOOT LAKE

Organisms per Liter; each Figure an Average of the Four Depth Levels

Organisms	Jan. 15, 1938	Feb. 19, 1938	Mar. 19, 1938	April 16, 1938	May 21, 1938	June 18, 1938	July 16, 1938	Aug. 20, 1938	Sept. 17, 1938	Oct. 15, 1938	Dec. 3, 1938	Jan. 28, 1939	Mar. 25, 1939
Coelsosphaerium		2				488	1,550	2,775	950	252			
Microcystis							600	2,800	250	85			
Anabaena						7,750	16,050	5,600	1,900	400			50
Aphanizomenon						3,500	42,250	1,900	500	250	50	250	
Melosira		1,000	250	500			500	450	400	400	7,500	1,500	350
Stephanodiscus		55	135	450	465		4	50			3,558	1,763	4,250
Synedra	14,667	4,250	10,500	135,500	750			1,250	3,850	750	12,500	63,250	27,500
Asterionella			1,500	11,750	85,250	12,750					3,350	15,500	308,000
Fragilaria		1,000		750	2,750		2,250	500	1,600		300		450
Pediastrum		1		4	21		20	8	10	4	14		
Ceratium	4		3	2	258	16,300	139	92	31	3		1	1
Codonella	11	2	11	20	12	2					14	11	75
Polyarthra	7			717	195	183	161	87	68	94	36		24
Keratella	272	116	131	448	1,033	35	1,036	118	95	104	507	504	174
Asplanchna				1		13			5	7	7		
Synchaeta							45	4	13	1		4	
Notholca							8				8		
Nauplius	607	58	27	266	119	35	24	28	31	28	80	70	39
Cyclops	807	107	86	57	100	7	6	12	9	13	52	47	16
Diaptomus			3		10	20	10	1		1	2		
Daphnia	1		1	5	10	19	1		1				
Bosmina	16	11	3	1	73	1	2		5	2	8		

so abundant a population of this diatom. However, in three collections, December, 1938, January and March, 1939, Stephanodiscus occurred in much larger numbers in the water bottle sample. Net counts were used, as the other would show a very haphazard distribution.

TABLE IV

NANNO-PLANKTON. MIDDLE OF TURKEYFOOT LAKE

Organisms per Liter; each Figure an Average of the Four Depth Levels

Organisms	Aug. 17, 1936	Sept. 19, 1936	Oct. 17, 1936	Nov. 14, 1936	Jan. 9, 1937	Mar. 27, 1937	April 24, 1937
Coelsosphaerium naeg.	......	19,813	......	......	......	......	......
Oscillatoria (small sp.)	......	......	......	......	......	......	33,250
Synedra (small sp.)	......	......	......	......	......	......	170,000
Amphora	......	......	......	......	......	......	......
Scenedesmus	500	625	1,258	1,500	......	......	8,750
Trachelomonas	1,750	8,000	3,438	2,063	......	......	......

Organisms	May 22, 1937	June 19, 1937	July 19, 1937	Aug. 20, 1937	Sept. 18, 1937	Oct. 16, 1937	Jan 15, 1938
Coelosphaerium naeg.	......	......	......	......	......	......	......
Oscillatoria (small sp.)	16,688	......	......	924,500	7,725,000	50,000	......
Synedra (small sp.)	36,563	......	36,000	2,538,500	450,000	95,000	......
Amphora	......	......	......	......	......	......	......
Scenedesmus	1,875	......	913	2,275	......	2,000	......
Trachelomonas	......	......	......	21,650	3,750	15,250	1,250

Organisms	Feb. 19, 1938	Mar. 19, 1938	April 16, 1938	May 21, 1938	June 18, 1938	July 16, 1938	Aug. 20, 1938
Coelosphaerium naeg.	......	......	......	......	......	21,750	......
Oscillatoria (small sp.)	......	......	......	......	......	......	......
Synedra (small sp.)	68,000	......	143,500	......	......	3,250	188,500
Amphora	......	......	......	......	......	......	......
Scenedesmus	......	......	6,250	......	......	1,500	750
Trachelomonas	6,000	3,250	10,750	1,000	500	3,350	2,000

Organisms	Sept. 17, 1938	Oct. 15, 1938	Dec. 3, 1938	Jan, 28, 1939	Mar. 25, 1939		
Coelosphaerium naeg.	......	......	......	......	......	......	......
Oscillatoria (small sp.)	667,500	21,250	122,500	390,000	......	......	......
Synedra (smal sp.)	311,250	22,500	58,750	......	......	......	......
Amphora	18,982,500	225,000	......	45,000	......	......	......
Scenedesmus	1,500	......	1,500	......	......	......	......
Trachelomonas	6,250	5,500	9,000	7,750	10,250	......	......

A few of the twenty-seven genera occurred in relatively fewer samples or in smaller numbers than others of their class. They were the blue-greens Aphanocapsa and Oscillatoria (a large species), the desmid Staurastrum, the Protozoa (or Algae) Mallomonas and Dinobryon.

The remaining 22 genera of net plankton appear in condensed tables. In these (Tables II, III) vertical distribution is lost, since each figure of organisms per liter is the average of all 4 depth levels. Figures 4 to 8, made from these, show the seasonal distribution.

The six nannoplankton kinds were secured only from water bottle collections. Tables showing vertical distribution of the six genera of nannoplankton are also omitted for want of room, but a condensed table giving the average figures of organisms per liter for the vertical range of four levels appears (Table IV). One plankter, the small Coelosphaerium, was omitted; it occurred in only two collections of the twenty-six, though in large numbers. Figure 3 shows the seasonal distribution of the five nannoplankton.

Some other plankton types were occasionally found, but so sporadically that inclusion in tables and graphs would have given little information. Among those recognized were Navicula, Euglena, Phacus, Cosmarium, Closterium, Gonium, Pandorina, Glenodinium, the rotifer Chromogaster (Anapus) and Chydoris. A few scattered diatoms were not recognized. Several kinds of rotifers, maybe six, appeared as individuals, rather widely scattered, mostly in rather poor condition, and were not identified.

It should be added that Dr. Taft in minute examination of some samples, found, besides the abundant kinds, some Chroococcus, Gomphosphaeria, Coelastrum, Sphaerocystis, Crucigenia, Oocystis, Eudorina; many of these were rare, or if not for a certain sample, were in the collections as a whole.

Dr. Noland in minute examination of some samples noted besides certain abundant ones, the following zooplankton, Peridinium and uncommonly various Ciliates mostly in rather poor condition in the preserved material, including Vorticella, Campanella, Lembus, Halteria and possibly others.

VERTICAL DISTRIBUTION

The vertical distribution could be seen only in the extended tables comparing the organisms per liter in surface, 4 m., 8 m., and 12 m. water. A study of all this data showed that there was rarely a uniform distribution from top to bottom, that the differences were not of much significance, that they were not consistent, that is that sometimes numbers were larger for a higher level than a lower, and at other times were smaller for the same higher level than the lower. In the case of most blue-green algae there was a tendency, expecially in times of maxima to have more at surface and 4 m. than in deeper waters, though not quite so pronounced a difference as expected from laboratory conditions in which these blue greens would rise to the top in bottles and centrifuged water. Among the nannoplankton a few striking differences occurred. When the organisms were most abundant, the tiny Oscillatoria and the tiny Synedra, August and September, 1937, August and September, 1938, and the Amphora, September, 1938, were excessively abundant in the upper levels, and relatively few in the two deeper levels. The same was true of the small Coelosphaerium, not listed in the table. In these few cases, there was a close correlation with water temperature, the abundance going with high temperature. (See further discussion under seasonal distribution.)

SEASONAL DISTRIBUTION

The average number of organisms per liter for 22 plankton genera and separately for 5 other nannoplankton kinds were used for construction of the figures (3 to 8), as noted above. The graphs give a picture of the distribution, but it must be remembered that they are semi-logarithmic. A zero line had to be added (despite any mathematical objections), arbitrarily below the lower base line, which stands for either 1 or 10 in various graphs, and for 100 in Fig. 3.

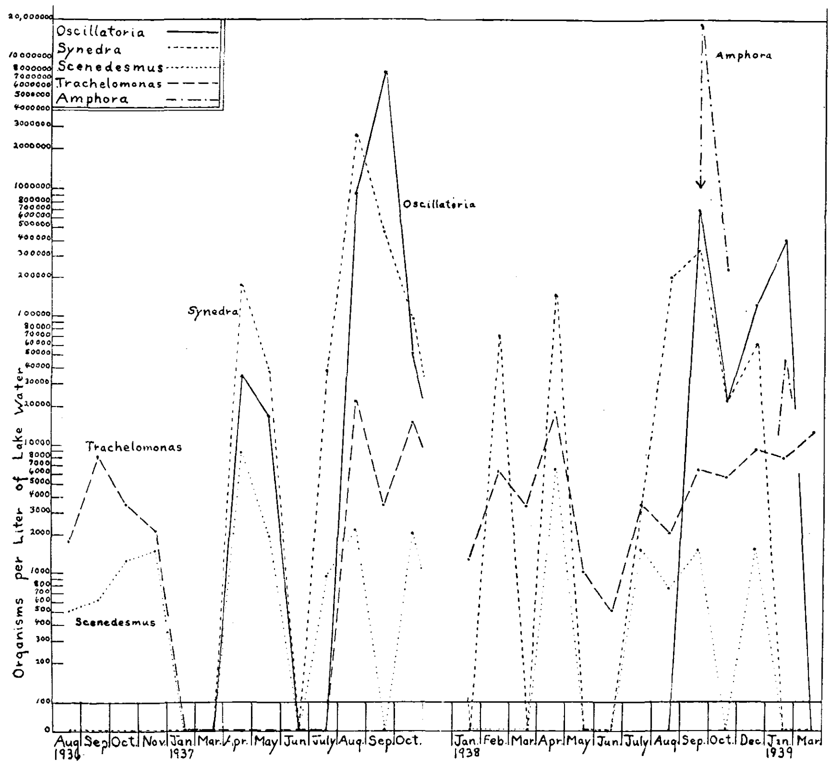

Fig. 3. Nannoplankton. Seasonal Distribution, from August, 1936, to March, 1939. Organisms per liter. Each reading is an average of four depth levels. Semi-logarithmic graph.

The various classes of plankton have long been recognized as having a somewhat typical cycle, with a period or two periods of maximum abundance annually, correlating approximately with the seasons. Information on this matter is summarized in texts of Whipple (1927) and Welch (1935). In the former, the seasonal climaxes are especially stressed (Chapter IX). Welch (pp. 236–239) also points out that despite seasonal periodicity there is much variation within a year and from year to year, and that instead of a taxonomic group being a unit, each plankter in the last analysis is practically a unit in itself. In the graphs presented here, each plankton kind is shown in its own curve, but with those of its own taxonomic group, so that it can be seen how closely the members of a class coincide in their pulses. It was thought that additional graphs representing total plankton of each class could be dispensed with.

CYANOPHYCEAE

The annual period of maximum development of blue-green algae is late summer. In this study the individual kinds of Cyanophyceae were seen to have their maxima not coinciding precisely and not at exactly the same time nor as large each year.

Coelosphaerium of two different types was found. One type (Tables II, III) was large, often in large colonies, though of such range of size that it might have been a mixture of C. dubium and C. kuetzingianum. Colonies always had a bright color and contributed materially to the water bloom and rose uniformly to the top of laboratory vials and in centrifuging. The other (Table IV) identified as C. naegelianum, was found only in water bottle samples in two collections. Its cells were smaller, colonies smaller and definitely of a paler color. The large Coelosphaerium (Fig. 4) attained a maximum in September in two of the three years, but was also abundant in August and even in October. It developed and declined slowly so that its season in which it thrived lasted from late June practically to November.

Microcystis was somewhat less abundant than Coelosphaerium, had a shorter period of development, but nevertheless rather similar distribution. One minor peak of development, but almost equal to the late summer peak of the year, occurred in April, 1937. (Figure 4.)

Oscillatoria of large size occurred infrequently. But in the nannoplankton graph a tiny filament identified as Oscillatoria was very abundant. In 1937 a minor peak was evident in April, followed by a complete decline, a major peak in August and September, with rapid decline in October. But the next year's distribution differed somewhat; the major peak, September, was much smaller, a great decline followed, but there was a large peak in January. (Figure 3.)

Anabaena on the whole showed consistency. The filaments were always prominent, rather long, the count being of such so-called whole filaments. Small pieces were counted as fractions. It was an important contributing cause of water bloom. Anabaena reached its peak earlier than Coelosphaerium, and attained greater numbers. In the two years of complete summer records, the peak was in July, but almost as high in August. Autumnal decline was slower than early summer increase. (Figure 4.)

Aphanizomenon was somewhat similar to Anabaena, but reached far greater numbers and was sometimes important in the water bloom. In two years the great peak was in June and July; unfortunately no record was available for those months in 1936, which had a very large peak in September with only a small decline in October. (Figure 4.)

It is evident that not alone in late August and early September when more or less water bloom appears, is the class as a whole prominent. Its season of thriving is much longer. There is a correlation with water temperature, of the class as a whole. But as noted above, Aphanizomenon which attained greatest numbers of all these listed among net-plankton, reached its greatest of all peaks one June, with somewhat less in July, and a big decline in August and more in September. The big June-July pulse was three times as high a peak as the next highest attained the preceding year in September. The third year the highest peak, one-fifth that of the highest of all, was centered in July. Water temperatures on the whole are 5° C. lower on the surface in June than in August. (See Table I, and Figure 2.) Other very

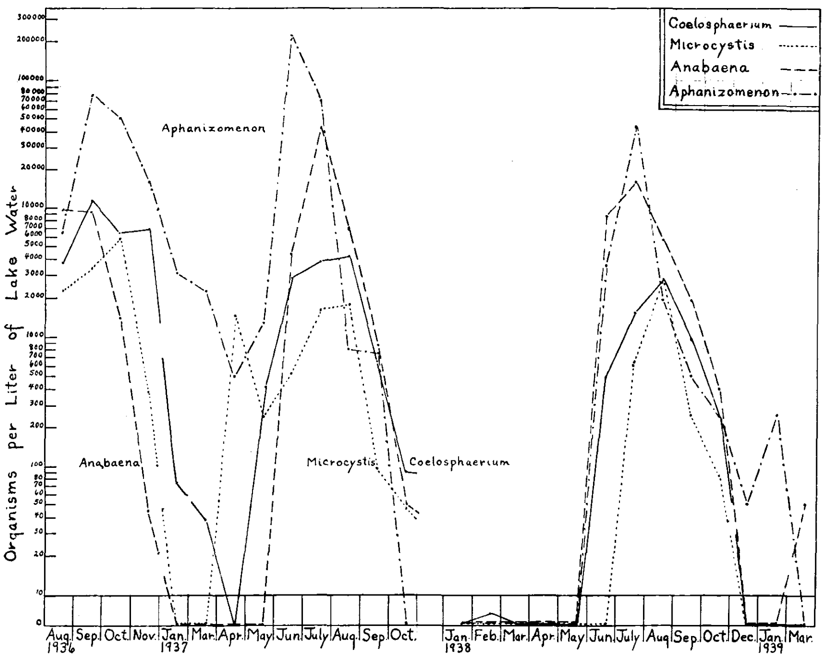

Fig. 4. Blue-green algae. Seasonal Distribution from August, 1936, to March, 1939. Organisms per liter. Each reading is an average of four depth levels. Semi-logarithmic graph.

abundant blue-greens, especially the small Oscillatoria of the nannoplankton, correlate their abundance more closely with the maximum temperatures.

Vertical distribution is not exhibited in the graphs. While much of the year the algae population differed only slightly at the several levels sampled, there was relatively far more increase at the surface, and nearly as much at 4 m., than in the deeper waters, at the late summer maxima or time of the water bloom. This, as was noted in temperature chart and graph, was the time of surface temperatures of 26° to nearly 28° C., and 25° to 26° C. at 4 m., but average temperatures of 19° C. at 8 m., and less at 12 m.

DIATOMACEAE

Diatoms are generally recognized as having a striking spring maximum and a secondary late fall peak, or the two pulses reaching about equal maxima. Whipple (p. 228) lists Asterionella, Tabellaria, Melosira, Synedra, Stephanodiscus, Cyclotella, and Diatoma, as being the chief genera exhibiting spring and fall maxima.

Melosira was not found distributed seasonally in quite this manner. There was no distinct spring peak, only a fair number throughout this as in most seasons. The only distinct peaks were in November, 1936,

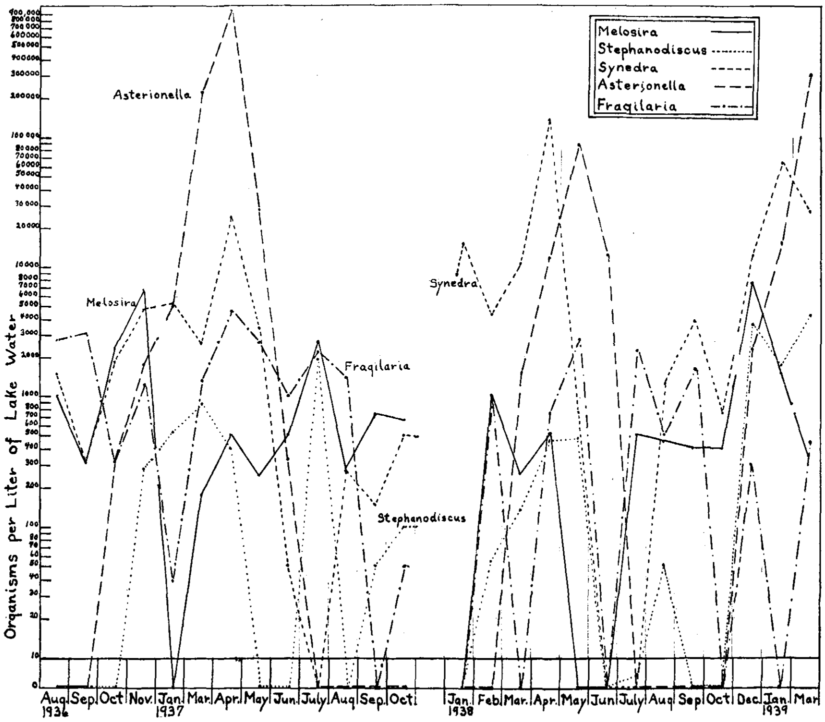

Fig. 5. Diatoms. Seasonal Distribution, from August, 1936, to March, 1939. Organisms per liter. Each reading is an average of four depth levels. Semi-logarthmic graph.

December, 1938, with the next largest pulses in July, 1937, and February, 1938. (Figure 5.)

Stephanodiscus was also found distributed in fair quantity in many months of the year, with a fairly broad spring peak, but also a July peak one year and a winter peak, December to January. In one year a long winter and spring pulse was continuous. (Figure 5.)

Synedra of a large species was prominent in net-plankton. (Figure 5.) A much smaller species, about one-fifth as long as the other, was found only in water bottle samples and shown in nannoplankton graph. The large net-plankton species was more widely distributed during the year and common except in early summer. There was a high April period definitely each year, also large numbers in fall and one high peak January, 1939. The tiny Synedra occurred in tremendous numbers in a late summer 1937 peak, and large numbers in a spring pulse each year, with two separate peaks in spring 1938, and also an extended autumn pulse the same year. The greatest number of all attained (August, 1937), was actually eight times the number of organisms attained in the second highest peak. A re-check showed no late summer occurrence whatsoever in 1936. This tiny Synedra and one other diatom of the nannoplankton (Amphora) were the only ones which had, and then really only in the greatest maximum, a far greater number in upper than in deeper waters. (Figure 3.)

Asterionella showed the greatest spring pulses and attained the greatest total numbers of all diatoms except the tiny Amphora in its one great splurge. An outstanding peak was attained in April, 1937, though a decidedly smaller one next year and that delayed until May. The last collection made, March, 1939, showed an ascending population that probably reached a month later some figure like that of April, 1937. (Figure 5.)

Fragilaria occurred at least as uniformly throughout the year as Melosira and Stephanodiscus, though at the same time exhibiting small peaks in April and May and other minor peaks in erratic arrangement. (Figure 5.)

Amphora, a very small diatom (recorded in the nannoplankton group) was found present only in September and October, 1938, and January, 1939. Strangely, it was not even found in the similar periods in either of the other two years as another re-check showed. Of course, a plankter as small as this might have been overlooked if it occurred only as a few scattered in a counting cell, among debris and larger plankton, but any such numbers would have been irrelevant. Furthermore, the enormous maximum, 19 million, as in all other figures used in making graphs, is an average of four samples from surface to 12 m. Deeper waters had smaller numbers and surface water about twice the average number. (Figure 5.)

CHLOROPHYCEAE

Green algae were not represented by any types that were predominant in the lake plankton, though various kinds occurred in very small numbers in irregular distribution and three were found in larger numbers. Even one of these, the desmid Staurastrum, was omitted from the graphs. It occurred in just eight of the 26 monthly collections. Largest numbers were recorded in May, both in 1937 and 1938, but otherwise distribution was sporadic.

Pediastrum is recorded in Figure 6. It was found in rather small numbers but in quite a few months of the year. Only slight peaks or pulses were shown, in spring and in summer; one of August, 1936, was highest; March, 1937, was next largest and among the lesser peaks was one in December.

Scenedesmus, among nannoplankton, has peculiar distribution, with a number of peaks of which the most consistent was an April peak. There were also separate small peaks in November, 1936; August and October, 1937; and July, September and December, 1938.

PROTOZOA

Only certain flagellates were present and numbers of ciliates which were relatively rare. Dinobryon, Mallomonas, Trachelomonas, Ceratium and Codonella were followed through the collections. It is real-

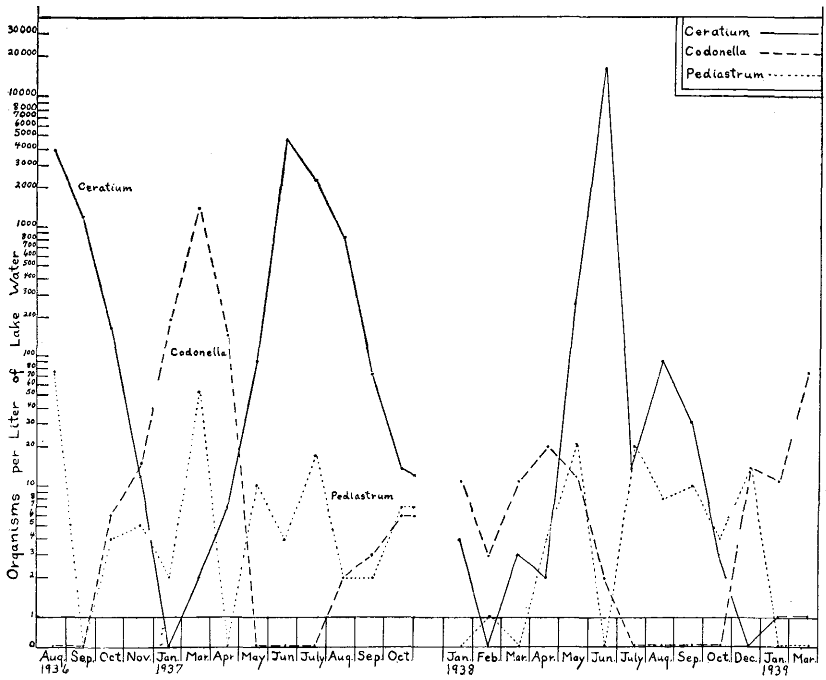

Fig. 6. Protozoa and a Green Alga. Seasonal Distribution, from August, 1936, to March, 1939. Organisms per liter. Each reading is an average of four depth levels. Semi-logarithmic graph.

ized that several of these types are classified as algae by various algologists, but for the present purposes they may well be grouped together here. Mallomonas and Dinobryon occurred less often and are omitted from the graphs. Their distribution seemed erratic. One decided peak for Dinobryon occurred in April.

Trachelomonas is on the nannoplankton graph (see Figure 3). The pulses were pronounced but not the same each year. An early autumn peak was most definite, but in one year a spring peak occurred, followed in fall by a gradually rising number that continued to increase somewhat through the winter and to next spring.

Ceratium (Figure 6) was a very prominent plankter, found nearly throughout the year. The great pulse occurred in a pronounced peak in June, though nearly as great a peak was reached in August when the first collections were made. The early summer pulse either continued somewhat, or repeated as another secondary pulse (August, 1938).

Codonella is a characteristic plankton ciliate having a lorica. It was present in many samples, but had a large peak in March of only one year, and minor peaks January, April, and December, and somewhat higher again in March following. (Figure 6.)

ROTIFERA

Rotifers formed a prominent group in the plankton. Rotifers are said to have their large numbers between June and November (Whipple, p. 235). Five genera were followed throughout. (Figure 7). Several

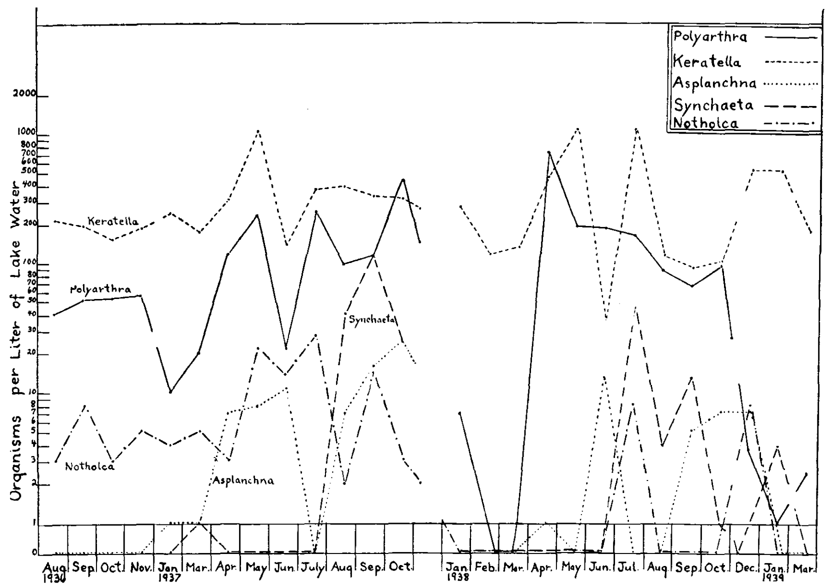

Fig. 7. Rotifers. Seasonal Distribution, from August, 1936, to March, 1939. Organisms per liter. Each reading is an average of four depth levels. Semi-logarithmic graph.

other kinds, not identified, were rare or scattered. Chromogaster was recognized, but also was apparently rare.

Polyarthra was found during nearly the entire year with only one considerable break in continuity in early spring one year. The highest peak occurred in one April, and this pulse decreased gradually during summer and late fall. In another year there were distinct though lesser peaks in May, July, and October.

Keratella (Anuraea) was the rotifer which was most uniformly distributed through the seasons. Increases that occurred resulted in a peak in May, and in May and July the next year, but with a quick decrease in June both years. The winter season did not show any minimum, in fact, in one winter the number ran far higher than the annual average.

Asplanchna had a far more restricted distribution, but variable. One year there was a small peak April to June and another August to October; another year a peak in June and one from October to December, whereas in another year none were found in samples of late summer and fall.

Synchaeta was likewise restricted, and numbers were small. A decided pulse occurred one September. In another year there were three, decreasing sized pulses, June, September, and January.

Notholca showed a little more continuous distribution for approximately a year with a general increase in late spring and summer but in another year it appeared less often with a slight peak in July and another in December.

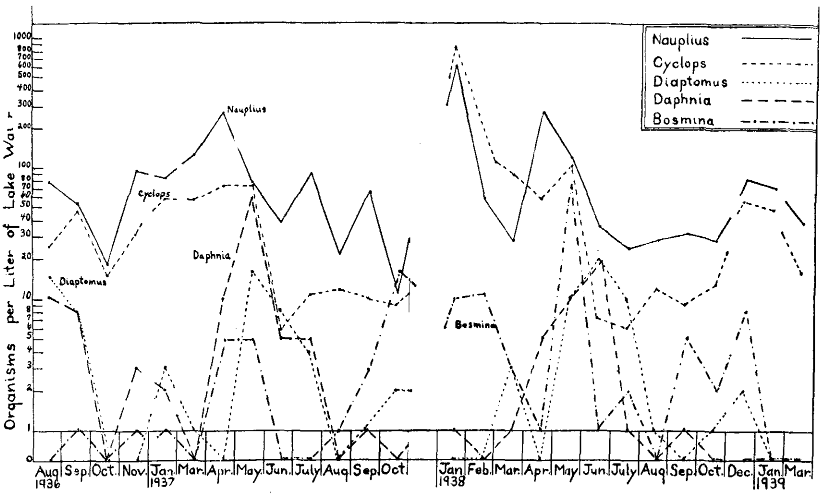

Fig. 8. Entomostraca. Seasonal Distribution, from August, 1936, to March, 1939. Organisms per liter. Each reading is an average of four depth levels. semi-logarithmic graph.

ENTOMOSTRACA

The smaller Crustacea are the largest of the normal plankton organisms, and though their numbers do not seem large, they make a prominent part of plankton life. Cyclops and their larvae, Nauplius, were really rather abundant, other types more occasional, and on the whole not very common. It is perhaps surprising that more Cladocera should not have appeared. (See Figure 8.)

Nauplius larva was found commonly during most of the year. It exhibited a number of slight pulses and declines. The most consistent peak was in April, but one January peak was far higher. Minima were in October. The Nauplius was that of Cyclops in most cases probably, though in this type of routine work it is not at all sure that Diaptomus larva was separable from Cyclops.

Cyclops had a distribution somewhat similar to Nauplius. An unusually high peak of development occurred January, 1938. Otherwise there was little consistent seasonal variation. Points of minima were in October, June and July. On the whole, the numbers were up well from the middle of the winter, through spring until May.

Diaptomus appeared in small numbers, but with decided pulses, going to vanishing points in samples after each pulse. Separate peaks were in succession in August, January, May, October, and the next March, June and December. There is at least a slight regularity in the intervals between these pulses, but they do not come at the same time from year to year.

Daphnia had, possibly accidentally, a distribution very similar to that of the Copepod Diaptomus; the pulses were, with some exceptions, practically at the same time. The highest peak was in May, 1937; one a year later in June was, however, only a third as high. Otherwise, no pulses were ascertainable. A fairly consistent low point occurred in October.

Bosmina appeared in smaller numbers than the other Entomostraca, on the whole. But there were also a few real pulses, the largest in October, 1937, a smaller one in the following February and a very large one in May.

SUMMARY

Plankton organisms were collected in one central pelagic station in Turkeyfoot Lake, from August, 1936, to March, 1939. In the 32 month period, 26 monthly collections were made. Months missed were chiefly in winter, but only once were two consecutive collections missed.

Temperature records were made and a table and graph of much of this data is presented.

Tests of dissolved O_2, CO_2, and pH colorimetric tests were made and a brief summary of this data is presented.

Plankton was collected by trap-net and water bottle and counts made under low power of all organisms as far as size permitted, from both collecting devices. A few kinds of real nannoplankton were secured only from the water bottle. Of those collected by both devices, the net counts were found most satisfactory for most of the plankton, but the water bottle counts best for most diatoms and one of the blue-greens.

Of many plankton kinds, 27 genera regarded as net-plankton and six nannoplankton were tabulated. Of the former, 22, and of the latter, 5 are presented in condensed tables and graphs.

Vertical distribution was studied, samples having been from four levels in all collections. No definite or consistent trends

in the vertical range could be ascertained, for any groups except in the case of some blue-greens and also of two of the smallest diatoms, and then only in times of great maxima, which were in a late summer water bloom when surface water temperatures were highest.

Seasonal distribution was the main objective. A set of six graphs, each graph comprising the group of related types, shows the seasonal cycle with pulses for all the main plankton genera. The classes had, as far as classes do have any uniform maximum pulses in definite seasons, the expected seasonal arrangement, including most prominently the one great late summer development of the blue-greens and the prominent spring pulse of diatoms. But in most groups there were many pulses, different for different genera, irregular through the seasons and differing somewhat in successive years.

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